**Introduction to Composites**
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**Lecture – 06**
**Properties of Composite Materials**

Hello welcome to introduction to composite materials. Today is the last day of this week, and what is we plan to do today is, continue our discussion which we started yesterday. And yesterday we had started discussing some of the important limitations, associated with composite materials. We had discussed advantages and then we started discussing limitations, because as an engineer it is important to understand what is are the benefits of a particular technology, and also what is are the associated limitations.

So, one important limitation which we had mentioned was that. Composites are in general an isotropic materials; that is their properties are different at in, the properties are different in different directions and what is; that means, in terms of practicality, is it is makes us more. it takes more requirement, more effort, more knowledge to understand their mechanics and also, and it takes more time, which means more money.

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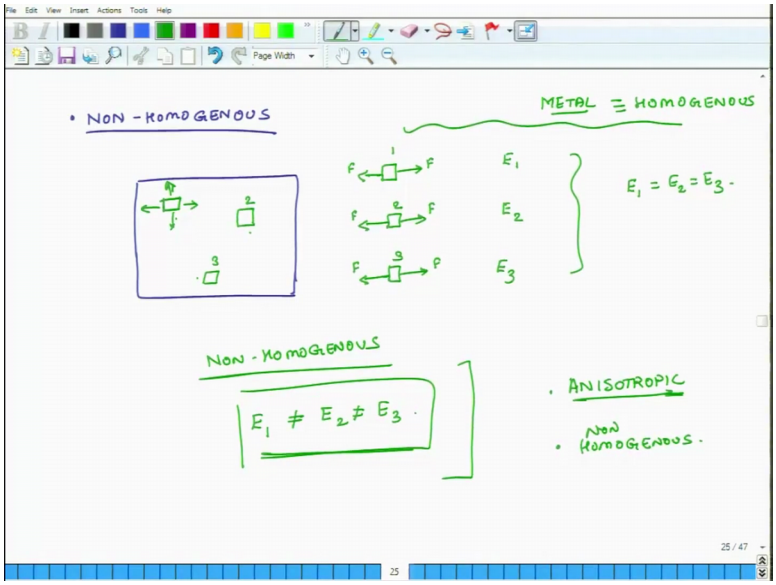


Another important thing is that they are non homogeneous, non homogenous. So, what is does non homogeneous mean. Again let us look at a piece of metal, and to understand it is young's modulus. I can cut a small piece of metal from location one, and the piece of

metal from location 2. Another piece of metal from location three, and then for each of these locations I can do a tensile test and when I do a tensile test from location one. Let us say I get modulus E 1 from location two, I get modulus E 2 from location three. I get modulus E 4 E 3, but this is a metal. So, in case of metal A metal is in general, if it is a decent quality metal is a homogeneous material, and because it is homogeneous, the values of E 1 will be same as E 2, will be same as E 3, but if the material is non homogeneous, then E 1 may not be necessarily same as E 2, and it may not be necessarily same as E 3 ok.

Now, we have defined composites as materials, which have at least two material constituents, and they care macroscopically distinct at a macroscopic level, they are different. So, if I look at them carefully at a macroscopic level, I will be able to figure out that, in this material is present, in this other region different materials present. So, they are non homogeneous, and because they are non homogenous properties at location one, properties at location two, properties at location three.

They may not be as, since essentially identical and that once again makes things more complicated. You have to have different theories to understand them, and it requires more time, more effort, more knowledge to understand and analyze composite materials. So, we have seen two important elements, that meta composites are anisotropic. And by anisotropic I imply that at the same point, you know at the same point. Suppose I just took this location one. So, this is at the same point, if I pull it in this direction, I will get one value of young's modulus. And if I pull it in this direction I may get another young's modulus.

So, that is meant by isotropy that the properties at a given point in the material, they are direction dependent, and then the properties are also dependent on the position. So, from location to location properties are changing. So, they are changing with respect to direction, and they are also changing with respect to location. So, these are two important limitations of composites, but then there are a couple of more challenges with composites. The other thing is that they are costly.

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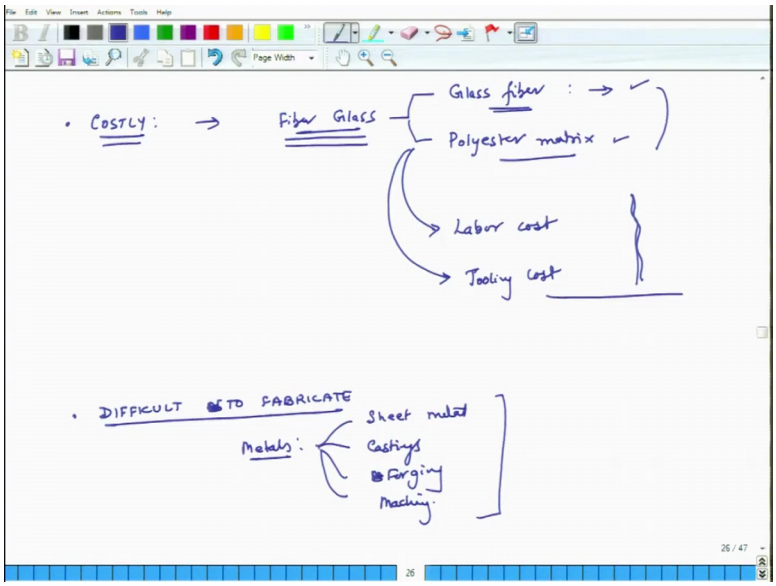


So, you take a kilogram of. So, what is the cheapest composite material is what is glass, the fiberglass. Let us say fiberglass for example, is made up of two components; glass fiber and some metrics. It could be a polyester, polyester matrix. Now if you find the. So, you go to market and you will find that the price of glass fiber per kilogram is more than the price of, let us say steel, regular steel, which we use or even aluminum. it is more expensive than even aluminum.

So, first component is more expensive, then if you go and buy polyester matrix. Again you will find that it is more expensive than metals; like steel and aluminum. So, both the constituents by themselves are more expensive, but then glass fiber is not just this, you also have to make it. So, there is also labor cost involved, labor cost is involved. So, all these things make things, these composites more expensive. They make them more expensive it is not only labor cost.

There are also tooling costs. So, for, suppose you have to make a cylinder of fiberglass the, somehow you have to make some tool which will help it wind the fiber in a circumferential pattern. So, also there are several reasons which make composites more expensive, and this is what is I am talking about the least expensive composite material. More expensive materials are Kevlar fibers, graphite fibers. They are much more expensive, and processing them is even more expensive. So, they are costly. So, the point what is I am trying to make is, that if we have to use composite materials it is great, but

then we have to make sure that when we use them, we are able to justify why that extra expense, which we are incurring to use them is reasonable.

Another limitation of composite materials is difficult to fabricate, difficult to fabricate. So, how do we fabricate regular materials? For instance in metals over last several hundred years, people have figured out very smart ways to use metals in different shapes and sizes. For instance you can have sheet metal processes castings, you can have machining, you know forging and you know machining and so on and so forth. So, a lot of standardization, lot of experience has been developed.

So, now, we can virtually make any shape out of metallic materials, but the same is not that much true of composites to make a unique shape. You have to develop a very unique process for composite material. So, that is why it is very difficult to manufacture, and it requires several steps of fabrication, it require several steps. So, it is time taking, it requires more expensive materials. It requires more skill in terms of labor, and as a consequence it is a very complicated process, are used to fabricate some good parts in realistic structures, made from composite materials.

So, this is another important limitation.

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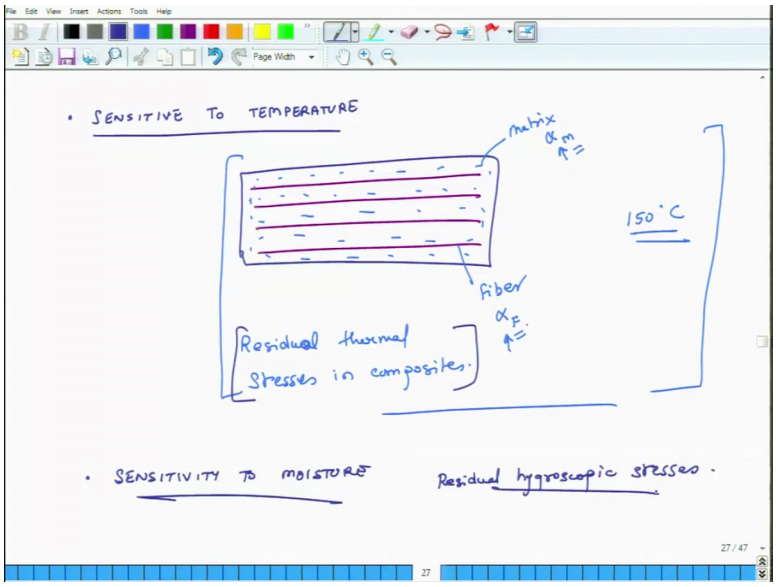


Then two more limitations sensitive to temperature and I will explain that, because earlier I had said that this is also an advantage, but in general unless we are super careful,

this can become an issue. So, what is does that mean. So, let us look at a very simple single layer composite, and this composite is made up of, let us say glass fibers. All running in one direction, and then it is surrounded and bonded together by matrix material. So, this is matrix, and this is fiber, this is fiber.

Now a single layer typically what is a lot of times, what is done, is if you have to just make a single layer composite, you put some fibers on a flat plate, maybe on a sheet of plastic we go, and then you put some epoxy over it and. So, if epoxy is in liquid state, it is a viscous fluid, that it is in liquid state and then it has to cure. So, to cure it what is they do is. So, it has to becomes, it has to become solid and that is called curing. So, to cure it a lot of times, then you add some extra chemicals in the epoxy or polyester, and then you raise the temperature, you raise the temperature.

So, the solidification reaction in the epoxy becomes fast, and you, may be you raise the temperature by 150 degree centigrade, let us say. So, if the room temperature is 25 degrees, you bring it 275 or 200 degree centigrade. So, at 200 degree centigrade, this epoxy gets cured, and when it gets cured all the fibers get logged into it. Now imagine what is will happen at 200 degree centigrade.

These fibers will expand by some amount. So, fibers will have some coefficient of expansion, let us say alpha f, and also the mixed matrix, because it is getting heated, it will also expand. And let us say it is expansion coefficient is alpha m. So, at 200 degree centigrade, everything will expand, and it will be in some state. Now everything is cured, and then the temperature of the composite comes down to the room temperature. It comes down to room temperature. what is will happen? Fiber will now try to contract. It will not have freedom to contract, when it was in fluid, it had freedom to expand.

But now it will try to contract, but the matrix is going to prevent it is contraction, because now matrix is solidified, and matrix will also try to contract and fiber. So, maybe if the expansion coefficient of fiber and matrix is equal, then no problem, everything will contract uniformly, and no problem, but in general fibers have much smaller expansion coefficients compared to matrices. So, matrix wants to compress more, contract more, but fiber does not want to come, if you know contract that much amount.

So, what is happens is that, matrix develops some sort of tension in it. And fiber develops some sort of compression a stress inside it. So, at the room temperature, there are inbuilt

residual thermal stresses in composites, because of the way things are being fabricated, and this is about just a single layer. Now if you have several layers. So, maybe one layer is having fibers like this, and another layer is.

Why having fibers like this. And if they are bonded together, there is a chance that there will be some thermal stresses in the residual, thermal stresses in the composite and because of that the composite plate. If we want to make a composite plate, it will not necessarily remain flat, but it may also curve, and we will learn the mathematics of that later it make curved. So, you wanted to make a flat plate, but you ended up making a curved plate.

So, this is what is I imply by cells, it being sensitive to temperature. So, you have to think about all these issues, and take care of them. Otherwise things can become complicated, and you may not get the desired results. The same problem happens in presence of moisture sensitivity to moisture, because some matrix materials, and in some cases, some fibers.

They absorb moisture, they absorb moisture from the atmosphere, and some materials matrix absorbs a different amount of moisture, and fiber absorbs a different amount of moisture, and because of this effect of moisture, they again go through volumetric changes, and because they are logged into a solid frozen matrix, they again get bent and distorted, and they develop residual stresses. So, in case of temperature, those are known as residual thermal stresses. In case of moisture, they are called as residual hygroscopic stresses. So, again you have to understand these things, and then do a good analysis of it, to make sure that you understand, and then accordingly you design your system.

So, that despite these problems, you are still able to get all the benefits of composite materials which we had discussed earlier. So, this is the overview of advantages and limitations. So, now, what is we plan to do probably, starting next. We will start next week is, we will start discussing about different materials used in composite systems. So, first we will talk about fibers in detail. What is kind of different fibers are available in the world, how are these different fibers made.

What is are the advantages and limitations of these different fibers. What is are their material properties, so that you get a physical you, some qualitative understanding of different types of fibers. Then we will discuss different type of matrix materials, and we

will also discuss some additives which are used while making composites to give them some special properties. So, that is what is we plan to accomplish in the next week. So, till then have a great day, have a nice weekend, and I look forward to seeing you next week.

Thank you very much. Bye.